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TECHNICAL TRANSLATION

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OPTICAL OBSERVATION OF ARTIFICIAL EARTH SATELLITES

Translation of Bulletin of the Stations for Optical Observation of Artificial Earth Satellites, No. 10, 1959. Published under the auspices of the Astronomic Council of the Academy of Sciences of the USSR (Moscow).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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/Following is a translation of the entire contents of the Russian-language periodical entitled "Astronomic Council of the Academy of Sciences of the USSR", Bulletin of Stations for Optical Observation of Artificial Earth Satellites, Moscow, No. 10, 1959, 30 pages./

1. DETERMINATION OF THE ORIENTATION OF ARTIFICIAL EARTH SATELLITES /AES/ IN SPACE FROM PHOTOMETRIC DATA

The determination of the life time of artificial earth satellites /1/, the study of a satellite's temperature conditions /2/, the study of the density of the atmosphere from the braking of artificial earth satellites /3/, and many other problems require a knowledge of the orientation of a satellite in space.

This is an attempt, undertaken by us, to solve the problem by determining the orientation of the satellite on the basis of photometric data.

At the present time, the fact of the change of brightness by satellites is generally known. In the paper of V. P. Tsesevich /4/ the basic causes of this phenomenon are indicated.

Let us assume that at our disposal are curves, which give the periodic variation of the brightness of a satellite, stipulated only (or basically) by the rotation of an elongated AES relative to the center of the mass. (The method of derivation of such curves will be described separately).

Experience shows that the amplitude of such a curve, even during the period of a single transit of a satellite, does not remain constant. This amplitude variation also affords the opportunity to determine the location in space of the rotational axis of the AES.

Let us assume as a first approximation, that the axis of rotation, producing the periodic variation of the brightness of the satellite, is perpendicular to its longtudinal axis or close to this.

Such a supposition is proximate to the truth inasmuch as if the axis of rotation of the second, and the rocket carriers of the first and especially of the third Soviet satellites were near their longitudinal axis, then for a certain diffusive nature of the reflection of light by the satellite to which for example the sinusoidal form of the curves of variation of their visible brilliance attests, the amplitudes of this variation could hardly achieve values of 6 - 8^m, since this would take place in actuality.

We also have direct confirmation of this hypothesis: according to data, derived from the flight of AES-2 at the beginning of its existence, the angle is found between the precession axis of the satellite and its longitudinal axis is equal to 86°. For AES-3, this angle was found to be equal to 84° /5/. There is also similar data for the American satellite Explorer I /6/.

In order not to judge the community of future discussions, we F
can break down into two directions the vector of rotation of an elong- 1
ated AES; one of these directions of which coincides with the longi- 1
tudinal axis of the satellite and the other, perpendicular to this axis, and we can examine the rotation around the orthogonal component.

During discussion of the computational results, we will again return to this problem, but in the meantime, we will consider that there is an elongated satellite, the rotational axis of which is perpendicular to its longitudinal axis.

It is obvious that during diffusive reflection, a larger area of its projection on the picture plane will correspond to the greater brightness of the satellite. (I. S. Astapovich referred to similar discussions applicable to meteors /7/).

In Figure 1, are presented three variants of the variation of such projections and accordingly -- of the brightness of the AES: Variant I - the axis of rotation of the AES is perpendicular to the topocentric radius -- to the vector of the satellite $\vec{\rho}$ (to the vector observer-satellite); Variant II - the axis of rotation of the AES is colinear to $\vec{\rho}$; Variant III - the intermediate (the value of the angle between the axis of rotation of the AES and the $\vec{\rho}$ lies between 0° and 90°). Position A corresponds to the maximum of the satellite's projection area on the picture plane. The satellite is visible from the side /and/ the observer notes the maximum brightness. The position Б is derived from the position of A during one-fourth of the period. The satellite turned by $\frac{\pi}{2}$ /and/ the observer notes the minimum brightness.

It is obvious that in case II, the amplitude of the satellites's change of brightness during one-fourth of a period will be practically equal to zero. In case I, it will be at the maximum. Case III is the intermediate.

The formula for the magnitude of the amplitude for the general case has the form: $A = A_0(1 - \cos\psi)$ (ψ - is the angle between $\vec{\omega}$ and $\vec{\rho}$, the constant A_0 can be changed from transit to transit).

If we designate the plane, which is perpendicular to the axis of rotation of the satellite, /as/ its equatorial plane, then generalizing preceding discussion can confirm the following: the maximum amplitude of a satellite's brightness variation is observed when the observer is in the plane of its equator (the axis of rotation

F 1 1 $\perp \vec{\rho}$, $\angle \psi = 90°$).

Proceeding from this, we suggest the following method for determining the axis of rotation:

At the moment t, when the amplitude of the brightness variation is the maximum, let us draw through the center of mass of the satellite a plane which is perpendicular to the vector $\vec{\rho}$. The equation of such a plane in a geocentric equatorial system of coordinates (Figure 2) is

$$\rho_x^0 x + \rho_y^0 y + \rho_z^0 z - (\rho_x^0 \tau_x + \rho_y^0 \tau_y + \rho_z^0 \tau_z) = 0 \qquad \text{(I)}$$

The axis of rotation, in accordance to the condition of perpendicularity to the vector $\vec{\rho}$, lies in this plane.

We copy this same equation for the moment t' which corresponds to the maximum amplitude during the observation of the same transit from another point or the observation of one of the subsequent transits:

$$\rho_x^{0\prime} x + \rho_y^{0\prime} y + \rho_z^{0\prime} z - (\rho_x^{0\prime} \tau_x' + \rho_y^{0\prime} \tau_y' + \rho_z^{0\prime} \tau_z') = 0 \qquad \text{(I')}$$

Intersection of planes (I) and (I') yields a straight line which in the construction is the axis of rotation of the AES.

If one copies the equation of the axis, determined by the simultaneous solution of equations (I) and (I') in canonical form, the formulas for computation of the components of the directing vector will be:

$$l = \begin{vmatrix} \rho_y^{c} & \rho_z^{c} \\ \rho_y^{c'} & \rho_z^{c'} \end{vmatrix} \qquad m = \begin{vmatrix} \rho_z^{c} & \rho_x^{c} \\ \rho_z^{c'} & \rho_x^{c'} \end{vmatrix} \qquad n = \begin{vmatrix} \rho_x^{c} & \rho_y^{c} \\ \rho_x^{c'} & \rho_y^{c'} \end{vmatrix}$$

Having equated l, m, and n to unity, we will obtain $\mathcal{L}$, M, and N the guiding cosines of the axis of rotation. Using them, we also easily obtain the equatorial coordinates of the trace of the axis of rotation on the celestial sphere:

$$\sin \delta = N \quad \text{and} \quad \operatorname{tg} \alpha = \frac{M}{\mathcal{L}}$$

Having determined the position of the axis of rotation of the AES, we determine the position of its rotational plane in the same manner. The light elements determine the position of the satellite in this plane. Thus, within the limits of the accepted hypothesis, the problem concerning determination of the orientation of an AES in space on the basis of photometric data, is completely solved.

In conclusion, let us note that a certain modification of the method elucidated here, obviously will permit applying it also to satellites of type 1958 δ, and to obtain brilliance curves which are difficult [to obtain otherwise].

Odessa Astronomical Observatory V. M. Grigorevskij

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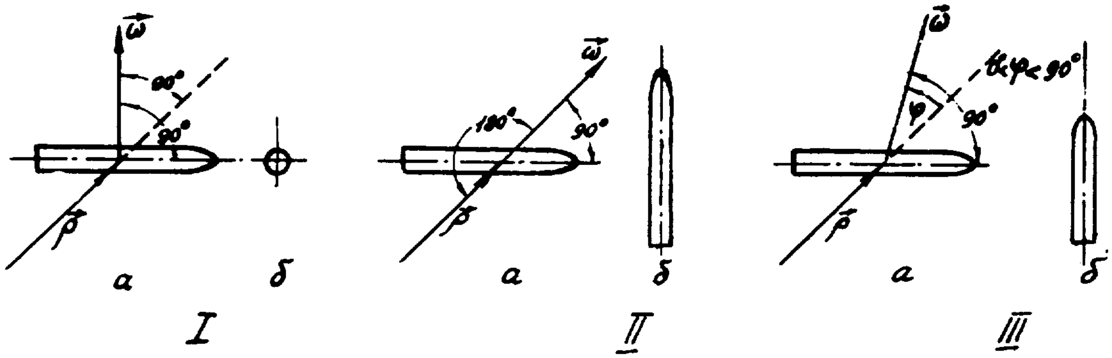

Figure 1.

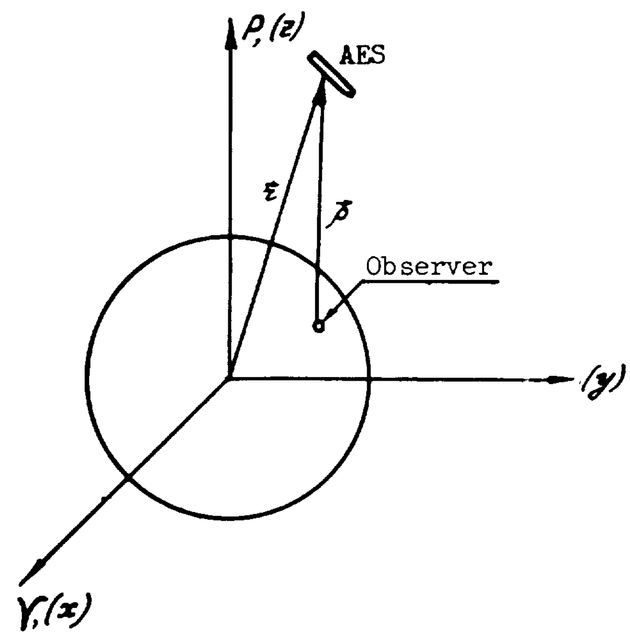

Figure 2.

2. ON THE ORIENTATION IN SPACE OF THE AES-2

Previously we have spoken about determining the axis of rotation of an AES by a method proposed by us; it is necessary to have the curves of variation of a satellite's brightness stipulated only (or fundamentally by its rotation relative to the center of the mass. Let us examine a method for the derivation of such curves.

Preliminary study of the factors, which determine the nature of the observed curve of brightness, showed that /these factors/ exert a fundamental influence (besides the rotation of the AES relative to the center of the mass):

1. Atmospheric absorption of light on the path from the satellite to the observer. In accordance to the instructions concerning AES photometry during observations, at the majority of the stations, the requirement for the uniformity of zenith distances and comparison of stars was sufficiently strictly observed, owing to which the effect of atmospheric absorption enroute from the satellite to the observer was excluded during the observational process.

In the event of non-observance of this condition, corrections were taken into account by the conventional method for the diversity of zenith distances.

2. The variation of the distance from the observer to the satellite.

From the evident formula $\frac{L}{L'} = \frac{\rho'^2}{\rho^2} = 2.512^{m'-m}$ we derive the correction which results in the satellite's brilliance to the absolute in the form: $\Delta m_{\rho^2} = 15 - 5 \lg z$ where ρ is expressed in kilometers and ρ' is taken equal to 1000 kilometers.

In Figure 1a are presented two independent series of observations of the brilliance of AES-2, conducted at Odessa during a transit on March 19, 1958 from two points separated from each other by ten kilometers. Figure 1b is the smooth curve 1a represented at a distance of 1000 kilometers according to the formula:

$$m_{\rho^2} = m_{obsv} + \Delta m_{\rho^2}$$

3. Variation of the illumination conditions of the satellite by the sun.

Here, we include two factors: the variation of the satellite's phase and the variation of the absorption of the terrestrial atmosphere of solar rays enroute from the sun to the satellite.

The variation of the satellite's phase, following the variation of the phase angle ϑ is essentially professed in the visual brightness of the satellite during the entire transit. Concerning the absorption of solar rays in the terrestrial atmosphere enroute from the sun to the satellite, the influence of this effect will be appreciable mainly in the immediate proximity of the terrestrial umbra, that is, when the solar rays, illuminating the satellite, pass near the surface of the earth. With the separation of the satellite from the terrestrial umbra, absorption is decreased in accordance to the decrease of the atmosphere's density in the path of the solar rays.

Obviously, the larger the phase angle ϑ , the further from the terrestrial umbra the satellite is.

Thus, the influence of both factors determining the conditions of illumination of the satellite by the sun, may be established in accordance with the variation of the phase angle.

Attempts at theoretically taking into consideration these effects are met with significant difficulties associated with the non-analytical form of the satellite, with the insufficiency of data concerning the terrestrial atmosphere, and so forth.

Therefore, such a calculation will be empirically conducted by us.

According to the formula: $\cos\vartheta = \vec{\rho}^{\,\circ}\cdot(\vec{\gamma} - \vec{\odot})^{\circ}$ (See Figure 2) calculates the cosign of the phase angle. In view of that, the shape of the curve $\cos\vartheta$ corresponds in both drawings to the shape of the curve of the satellite's brightness variation, corrected for the variation of distance, /and thus/ we find the dependence of the satellite's brightness on illumination condition in the equation $m\rho^2 = f(\cos\vartheta)$. This dependence was found to be linear (Figure 1c) correct to the effect of the AES rotation relative to the center of the mass.

For each transit, the coefficients a and b in the formula $m\rho^2 = a + b\cos\vartheta$ were computed by the least squares method. After this, the absolute brightness of the satellite resulted in the illumination condition when $\vartheta = \frac{\pi}{2}$, which were taken by us as the standard ones according to the formula $m\rho^2_{\frac{\pi}{2}} = m\rho^2 - \Delta m\,\vartheta$ where

$$\Delta m\,\vartheta = m\rho^2/\vartheta - m\rho^2/\tfrac{\pi}{2} = b\cos\vartheta$$

(Figure 1d) represents the brightness curve of a satellite reduced to standard conditions $\rho' = 1000$ km and $\vartheta = \frac{\pi}{2}$.

4. The parallactic distortion of the curve of a satellite's brightness.

As is clear from Figure 3, the directly observed topocentric maximum of AES brightness corresponds to the lunar period and each subsequent maximum will be observed not over the half-period $\frac{P}{2}$ but over the $\frac{P}{2} \pm \frac{\varphi}{360^\circ} \cdot P$ (the sign will depend upon the direction of rotation of the satellite). Illumination of the deformation of the brightness curve along the time axis requires a knowledge of the orientation of the rotational axis of the satellite. However, such a deformation is not professed in the observed amplitude of the brightness variation which is required for the determination of the position of the axis and therefore is not taken into account.

F11 Thus, for computation of the orientation of the rotational axis, curves were used by us presenting the form which is in Figure 1c.

Tentative calculations have been conducted according to the observation data of the brightness of AES-2, which was made at Odessa during four transits from March 19 to 21 of 1958. These transits were observed independently by three (Numbers 9, 10, and 11) and even by four (Number 14) by the observers (see Table 1). Comparison of the observations permitted reliably determining the course of the satellite's brightness variation. The averaged curves were rectified by the above described method. The moments of an amplitude's maximum of light variations were determined according to the rectified curves and the direction cosigns of the topocentric radius-vector, computed for these moments, were utilized for determination of the orientation in space of the rotational axis of the satellite according to the method described in our preceding paper.

A summary of the results of such determinations is given in Table 1 (in the first column are indicated the conditional numbers of the transits). (See page 11.)

If one changes to opposite signs the direction cosigns in the last two lines, which give the second end of the axis, then the results, with the exception of pair 10-12, coincide quite well. The deviation in the case of pair 10-12, obviously, may be explained by the fact that both planes, containing the axis of rotation, were found to be almost parallel and an even larger error in the determination of the moment of the amplitude's maximum of light variations would have resulted in noticeable errors $\mathcal{L}$, m, and n (in the first approximation, we consider that the amplitude's maximum coincides with the **highest maximum** of the brightness curve). Average (excluding 10-12) values of the coordinates of an axis' trace on a celestial sphere, are:

$$\bar{\alpha} = -74.^\circ 9 \qquad \bar{\delta} = -25.^\circ 9$$

Individual values of α and δ are well placed on the circumference with the center's coordinates $\alpha_y = -73°$, $\delta_y = -24°$ and with a radius of approximately 4° (let us recall that according to radio observations, the angle of the rotational axis of AES-2 with its longitudinal axis is equal to 86°).

However, the utilized observations constitute only 10% of the available ones and the question concerning the reality of such a circumference can possibly be solved only after the complete processing of all observations.

In conclusion, let us use this occasion in order to thank Professor V. P. Tsesevich and also Professor V. V. Sharonov and Reader I. S. Astapovich who have examined this and the preceding article in manuscript forms for a series of valuable notations and consultations employed by us in this paper.

Odessa Astronomical Observatory V. M. Grigorevskij

Table 1.

No. of Transit	$\mathcal{L}$	M	N	M/$\mathcal{L}$	UT 1958 III	α	δ	$\alpha - \bar{\alpha}$	$\delta - \bar{\delta}$
9-10	+0.271772	-0.834569	-0.479209	-3.070844	19.080	$-72^\circ.0$	$-28^\circ.6$	$+2^\circ.9$	$-2^\circ.7$
9-12	.190419	.870229	.453849	-4.570074	19.572	-77.7	-27.0	-2.8	-1.1
9-14	.186903	.872072	.452847	-4.665907	19.894	-77.9	-26.9	-3.0	-1.0
10-12	-0.481981	+0.731547	-0.482981	-1.517792	19.606	-56.6	-28.9	-	-
10-14	.329449	.873967	+0.344607	-2.667990	19.928	-69.5*	+20.2	+5.4	+5.7
12-14	.193609	.872744	.447994	-4507771	20.420	-77.5*	+26.6	-2.6	-0.7

* In accordance with the symeds $\mathcal{L}$, m and n it is necessary to add π to α.

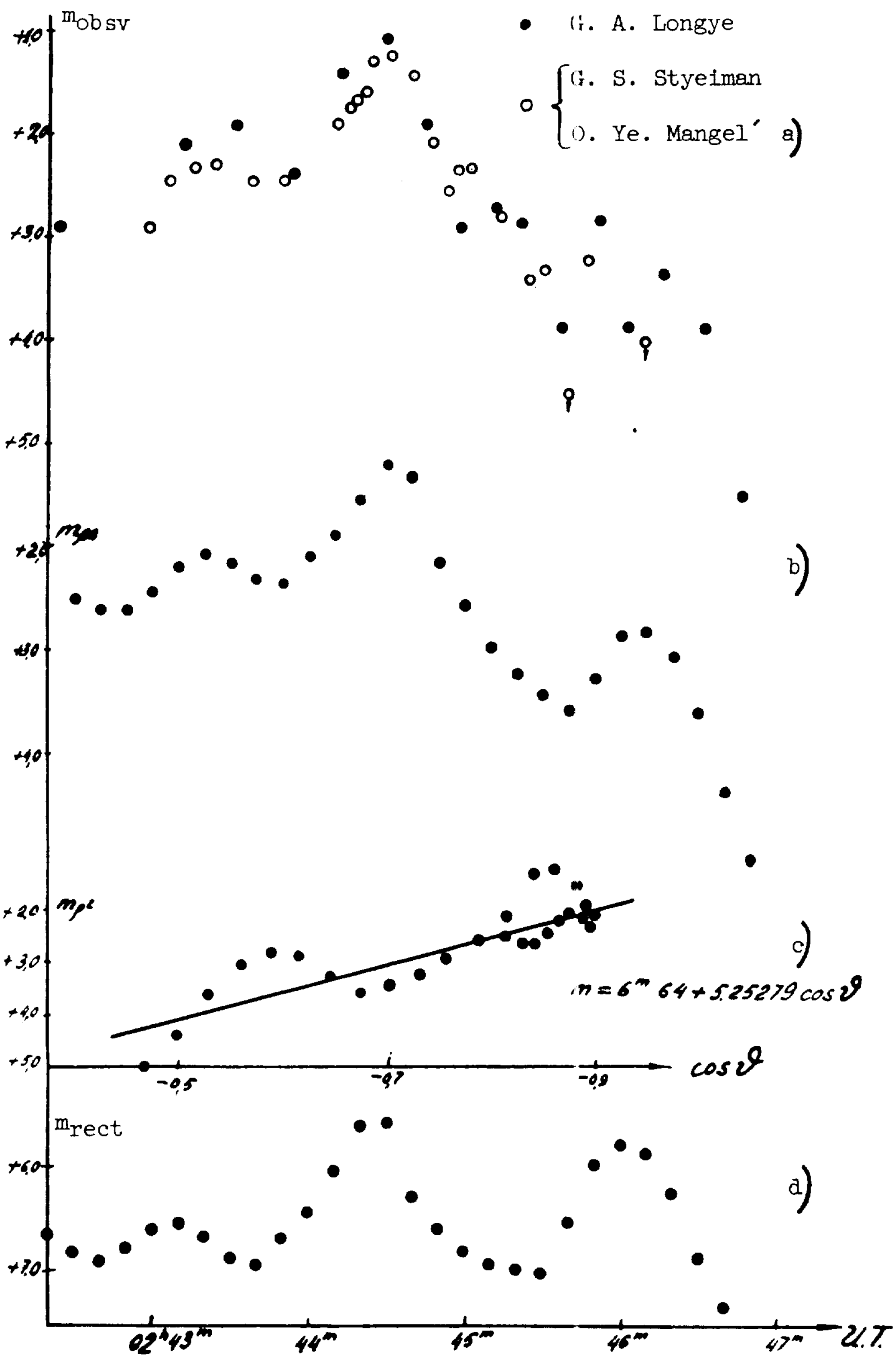
m obsv
G. A. Longye
G. S. Styeiman
O. Ye. Mangel´
a)
b)
c)
d)
m rect
m = 6m 64 + 5.25279 cos ϑ
cos ϑ
-0,5
-0,7
-0,9
02h43m
44m
45m
46m
47m
U.T.

Figure 1.

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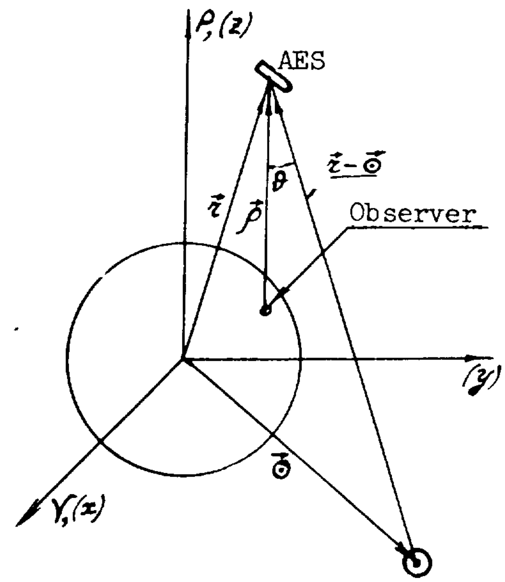

Figure 2.

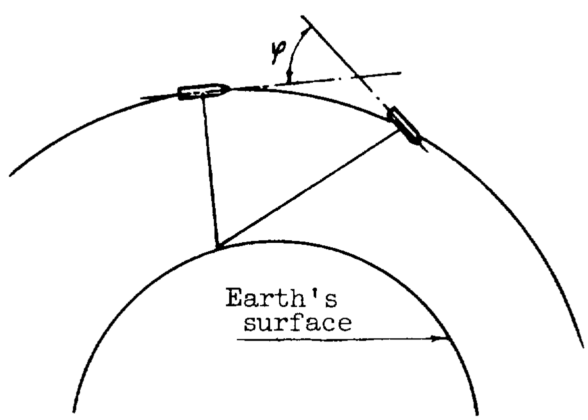

Figure 3.

3. ON THE ORIENTATION OF AN ELONGATED SATELLITE AS DERIVED FROM OBSERVATIONS OF MAXIMUM BRIGHTNESS

In contrast to AES-2, where there are only six occurrences of simultaneous photometry of a satellite at several stations, photometric observations of the rocket-carrier of AES-3 are "multiples" in the majority of cases.

Upon examination of the huge quantity of observation materials, obtained by Soviet AES observation stations, we turned our attention to the quite numerous occurrences when the moments of the maximums of the rocket's brightness observed during the same transit from two or more different points of the terrestrial surface coincide within the limits of accuracy of the observations.

The data permit determining the orientation of the rocket in space.

As previously*, we consider that the rocket disseminates light diffusively. (*See in the present issue the article "Determination of the Orientation of an AES in Space Using Photometric Data"). Such a hypothesis is in the case of the rocket-carrier of AES-3 a firm confirmation for the simultaneous observation of the brightness maximum from points very remote from each other. In Table I in the capacity of an example are presented data concerning the three simultaneously observed maximums (d -- is the distance between observation points, and r -- is the length of the geocentric radius-vector of the rocket at the moment of observation).

Table I

Moment of the Overall Max UT						Observation Points	d km	r km
1958	VII	24	23^h	07^m	$18^s.2$	Vil'nyus-Orenburg	2300	7200
	VIII	11	18	47	23 . 6	Odessa-Orenburg	1900	7300
		13	18	27	59 . 0	Odessa-Tashkent	2850	7350

A smoothly reflecting satellite, located at an altitude of approximately 950 kilometers above the surface of the earth, can almost form on /_the earth's surface/ a blick almost 3,000 kilometers in diameter.

Thus, at a certain moment, the brightness maximum of an elongated satellite can be observed by two observers who are quite remote from each other. At this moment, its longitudinal axis is perpendicular to the first as well as the second vectors of the "observer-satellite" and consequently is co-linear to their vector product. In other words, at the indicated moment, the cross drift of the longitudinal axis of the satellite coincides with the cross drift of the vector product of the topocentric radius-vectors of the satellite.

The available observation material for 1958 δ_1 permits obtaining a large quantity of such "instantaneous" positions of the axis. Any two of them determines by itself the plane of rotation of the rocket. Their vector product will give the orientation of the axis of rotation (correct to the perpendicularity of the rocket's axis of rotation of its longitudinal axis).

If the axis of rotation of an elongated satellite is perpendicular to the longitudinal axis, one can also determine it using several other considerations. The simultaneous brightness maximum (although also different in clarity) for two or more observers will come at that moment when the longitudinal axis of the satellite will become perpendicular to the plane in which the topocentric radius-vectors lie. By virtue of perpendicularity to the longitudinal axis, the axis of rotation will also lie in the plane of the radius-vectors.

Having constructed the same plane for the other two observers, who have observed the maximum simultaneously, we will obtain the direction vector of the axis of rotation at the intersection of a pair of such planes.

As was to be expected, the axis of rotation, obtained using two positions of the longitudinal axis and the intersection of the two planes formed by the topocentric radius-vectors, was found to be the same:

$$\vec{\omega} = \vec{\rho}_3 \begin{vmatrix} \rho_{1x} & \rho_{1y} & \rho_{1z} \\ \rho_{2x} & \rho_{2y} & \rho_{2z} \\ \rho_{4x} & \rho_{4y} & \rho_{4z} \end{vmatrix} - \vec{\rho}_4 \begin{vmatrix} \rho_{1x} & \rho_{1y} & \rho_{1z} \\ \rho_{2x} & \rho_{2y} & \rho_{2z} \\ \rho_{3x} & \rho_{3y} & \rho_{3z} \end{vmatrix}$$

where $\vec{\omega}$ -- is the direction vector of the axis of rotation, $\vec{\rho_1}$ and $\vec{\rho_2}$ -- are the topocentric radius-vectors for the first pair of observers, and $\vec{\rho_3}$ and $\vec{\rho_4}$ -- are the same /topocentric radius-vectors/ for the second pair.

One should note that the method suggested here of determining the orientation of an elongated satellite is more general than the method used by us for AES-2*): it does not require a knowledge of the entire curve of the satellite's brilliance and primarily discovery of the longitudinal axis of the AES is carried out without any hypothesis whatsoever with regard to the mutual positions of this axis and the satellite's axis of rotation.

Moreover, in the event that among the obtained curves of brightness of a satellite, type 1957β type by observers sufficiently remote from each other the maximums of which are such that they coincide, we obtain the opportunity of checking the hypothesis of perpendicularity of the satellite's axis of rotation of its longitudinal axis. For this, it is necessary to determine the plane of rotation of the AES directly (using the method of coinciding maximum) as well as the plane which is perpendicular to the axis of rotation (using the method of maximum amplitude).

Comparison of the results will also serve as a check. Coinciding maximums have not been found unfortunately, among the few available multiple observations of AES-2.

Check calculations will be made for the 1958 δ_1 satellite.

* See, in this issue, the article "On the Orientation in Space of AES-2".

Odessa Atronomical Observatory V. M. Grigorevskij

4. VISUAL BRIGHTNESS OF THE THIRD SATELLITE AND ITS VARIATION

The rotation of the cone-shaped satellite-3 around the axis, the location of which is still not known, produces a very non-uniform variation of its visual brightness. This satellite achieves the maximum brightness at the present position of its orbit (1100 km) above Europe $2^{m}_{\cdot}5$. At the minimum, it is not visible even with the AT-1 and binoculars ($\sim 9^{m}$). From 400 observations, obtained at Potsdam (using 47 passes), during which the brightness varied photographically down to $5^{m}_{\cdot}2$ and was evaluated visually for $m > 5^{m}_{\cdot}2$, the revealed average value of brightness is equal to $4^{m}_{\cdot}8$. In spite of such a comparatively propitious average value of brightness for observation, the observers were successful in detecting the satellite only during individual transits but even on these occasions, it was frequently lost immediately after detection but even then the /observers/ succeeded in measuring its position. This proceeds from the fact that the relationship of visibility conditions to non-visibility conditions is quite diverse depending on the position of the orbital plane relative to the sun and the observer, that is, it is favorable (2 : I) during positions of the orbit on the opposite side of the sun and unfavorable (I : 5), if it is located in line with the sun. The border between visibility and non-visibility is taken here as $6^{m}_{\cdot}5$.

Investigation of 47 curves of brightness, obtained at Potsdam in April and May of 1959 and sometimes embracing up to three maximums, shows that two clearly expressed types of brightness maximums exist. Acute maximums with a duration of an average of 50 seconds (from the development of brightness from 5^{m} to coincidence up to 5^{m} and flat maximums with a duration from 100 to 150 seconds are encountered. With regard to the limiting magnitude of brightness, acute and flat maximums do not differ. These limiting magnitudes lie in a range from 2.5 to 4.8 stellar magnitude and show the clear dependence on the distance of the observer-satellite (according to the law of the square of the distance).

In Table I (the second column) are given the results of computation of the visual brightness of a hemisphere's surface which is equal in magnitude to the convex surface of the third satellite's bottom ($\sim 4.8 \cdot 10^{4}\, cm^{2}$) at distance $\mathcal{D}$ assuming a complete specular reflection.

Table I

Distance $\mathscr{X}$ in km	Visual Brightness Computed	Visual Brightness Observed
1100	+ 3.2	+ 2.8
1200	3.5	3.7
1300	3.7	3.7
1500	4.0	4.2
1800	4.4	4.5
2200	5.0	4.7

These values concide well with the average individual values of the observed brightness maximums (the third column). A more detailed study of the maximums shows that the ratio of the number of acute to flat /maximums/ corresponds to 2:1. Hence, it is possible to draw the conclusion that acute maximums emerge as a result of the reflection on the lateral surface of the cone at a time when the flat maximums emerge during the reflection from the convex bottom of the cone. On the average, the acute maximum comes after a flat one by 2 minutes 40 seconds. After an acute maximum, either an acute one or a flat maximum follows again. In the first case, this takes place after 4 minutes 30 seconds, and in the second, again after 2 minutes 30 seconds. The clearest forms of maximums and the intervals of time between them are expressed during transits of a satellite which are near the zenith and are strongly distorted during low transits. A series of differing maximums acute-acute-flat - acute permits determining the period of rotation P = 2 (2 minutes 40 seconds plus 4 minutes 30 seconds = 9 minutes 50 seconds.

Computation of the geometry of the observed transits (using data of the American ephemeral service) shows that during unfavorable transits, reflection on the lateral surface of the cone is just not possible. This is explained by the fact that the third satellite, in spite of accurate ephemerides and the readiness of the observers, was nevertheless not detected during many observations.

For further investigation of the regularities of brightness variation of the third satellite, evaluations of the brightness are quite desirable and these evaluations should be accomplished at sufficiently remote locations of the orbit by other stations. Besides an evaluation of the brightness, only the precise moment is still required; determination of the coordinates is not required.

Potsdam Observatory
German Democratic Republic

U. Gyunttsel'-Lingner

5. DETERMINATION OF TOPO- AND GEOCENTRICAL DISTANCES OF A SATELLITE AND ITS HEIGHT ABOVE THE EARTH'S SURFACE

I

We will assume that during the course of several revolutions of a satellite, its motion is Keplerian and that it will describe an ellipse with one of the focal points at the center of the earth.

Let us introduce the following symbols.

The topocentric data concerning the satellite are:

d -- is the distance from the observation point to the satellite;
Z -- is the zenith distance taken from the continuation of a line connecting the center of the earth and the observation point;
μ -- is the angular velocity;
σ -- is the angle between the vector of the orbital velocity and the surface of the celestial sphere, $0 \leq \sigma < \frac{\pi}{2}$

Data concerning the orbit of the satellite are:

r -- is the radius-vector (geocentric distance);
a --- is the major semi-axis;
P -- is the sidereal period of rotation;
v -- is the velocity

Other data are:

R -- is the distance from the center of the earth to the observation point (the station);
m -- is the mass of the artificial earth satellite or moon;
$m_\oplus$ -- is the mass of the earth;
f -- is the gravitational constant.

From celestial mechanics /1/, it is known that $d = \frac{v \cos \sigma}{\mu}$

$$v = \sqrt{f(m_\oplus + m)} \cdot \sqrt{\frac{2}{r} - \frac{1}{a}} = \frac{2\pi a}{P}\sqrt{\frac{2a}{r} - 1} \qquad (1)$$

$$\frac{a^3}{P^2} = \frac{f(m_\oplus + m)}{4\pi^2}$$

Using geometric considerations, it is easy to conclude that

$$\frac{d}{R} = \sqrt{\left(\frac{r}{R}\right)^2 - \sin^2 z} - \cos z \qquad (2)$$

Knowing the coordinates of the station, the satellite's period of rotation, and its equatorial coordinates, and the angular velocity for the corresponding moment of time, we obtain a single equation with two unknowns r and δ from the system of equations (1) and (2):

$$r = R\sqrt{\sin^2 z + \left[\cos z + \frac{2\pi a \cos\delta}{\mu P R}\sqrt{\frac{2a}{r} - 1}\right]^2} \qquad (3)$$

Without taking into account for the present the determination of δ, let us note that for actually encountered occurrences, one can solve by means of integration equation (3) relative to r, whereupon successive values of the approximation of r coincide with the unknown /quantity/ quite rapidly. For the zero approximation of r, one should assume a.

Using the found /_quantity/ r, it is easy to determine the altitude of the satellite above the surface of the earth, having assumed its form, for example, to be a spheroid.

Formula (2) permits finding according to the radius-vector the topo-centric distance of the satellite at any point of the visible trajectory.

The radius-vector, altitude, and topocentric distance of the satellite are determined in accordance to (2) and (3), so precisely that the original suppositions concerning the satellite and all numerical data including even the angle δ correlate the validities.

The value of angle δ can be found through elements of the orbit but this is not included in our problem. Therefore, we will indicate certain other methods of evaluating the angle.

The transit of the satellite in the altitudes circle, where the angular altitude above the horizon is greatest (but not at the meridian!) we will call the culmination of the satellite. At this point, besides $z = min$, $\mu = max$ and the angular velocity of the satellite are equal to zero.

Let us note, that photographs at the culmination are frequent and are made whenever possible during each observed transit of the satellite, since from such observation to the satellite, located at the nearest distance from the observer, its position in orbit can be more precisely determined.

For the culmination, one can assume with good approximation that $\delta = 0$ which is equivalent to finding in the photograph of a satellite /its/ trace points which are characterized, for example, by the symbol $z = min$. As the example showed in Section III it is not difficult to find this point graphically with an error of $|\Delta\rho| \leq 1 \div 2^{\circ}$ in accordance to the trace, but if one finds $z = min$ analytically then it is even more precise. It is obvious that $|\Delta\delta/\Delta\rho| = 1 \div 2'$. Errors of Δr and $\Delta\delta$ of the corresponding r and δ are associated with themselves, whereupon $\Delta r = r^{-1} d (d + \cos z) tg\delta \cdot \Delta\delta$ (the distances are in units of the terrestrial radius). Near the culmination $\delta = \Delta\delta$ then when $r \leq 1.5$, that is, for almost all satellites launched up to now, we have $|\Delta r| \leq 0.0001 |\Delta\delta'|^2$ Hence, an error of δ by $\pm 1 \div 2^{\circ}$ yields an error of r by $\pm 0.0001 \div \pm 0.0005$. (4)

If that portion of the orbit, which corresponds to the visible trajectory of the satellite in the celestial sphere, is considered as a radius of a circle which is equal to the radius-vector of the satellite at culmination, then such a replacement of the ellipse by the circle will yield for δ the error $\Delta\delta_{ell}$ (the actual value of $\delta_{ell} = \delta - \Delta\delta_{ell}$), whereupon $tg\Delta\delta_{ell} = \frac{e^2 \sin 2E}{2\sqrt{1 - e^2}}$ where "e" -- is the eccentricity, and E -- is the eccentric anomaly. For satellites up to this time, it was $e \leq 0.2$. Thus, $|\Delta\delta_{ell}| \leq 1^{\circ}$ and $|\Delta r| \leq 0.0001$. In the event of a zenith transit,

$$\sin\delta = \frac{R}{r} \sin z \tag{5}$$

In the event of any transit, it is not difficult to obtain the expression for δ, but its derivation is rather complex for practical utilization and therefore, it is not cited.

Let us note certain conclusions.

First, according to photographic observations of the coordinates and the angular velocity of the satellite at culmination and according to the known period of rotation, one can compute the radius--vector independently of the orbit's elements except for the period of rotation, or its equivalent, independently or any other observations whatsoever except for information from which the period is determined. In other words, it is possible to determine the radius--vector using a single observation of a satellite at one station, taking into consideration, that the period of rotation can be found with a sufficient degree of accuracy, for example, using radio technical or optical observations at the same or any other station. Hence, it is clear that for culmination of the satellite it is quite expedient, along with the equatorial coordinates and the corresponding moments of time, to determine at the same point and to announce the angular velocity and the positional angle of movement.

Second, calculation of the topocentric distance of the satellite through utilization of its zenith distance and radius-vector is more simple than by the standard formulas of celestial mechanics. Another application of formula (2) is also interesting: if simultaneous with photographic observations of the satellite's coordinates one conducts with the assistance of radio technical means the determination of the topocentric distance then it is possible to find the instantaneous radius-vector of the satellite.

Third, it is assumed that owing to the simplicity of the calculation (see also the approximated formulas in Section II), the presented method of determining the geocentric and topocentric distances will also find practical application for the solution of a series of problems emerging during photometric and astronomical observations of satellites. In particular, it is necessary to know the approximated topocentric distance for carrying out evaluations of brightness at a standard distance and for computation of the refracted parallax and the aberrated time during the determination of coordinates. Moreover, according to formulas (1) and (2), it is possible to forecast the angular velocity at culmination for photographing weakly visible satellites using compensation cameras of the visible motion of the satellite.

II

As a consequence of the rapid and irregular movement of the satellite along the celestial sphere, its precise angular velocity μ must be determined namely at the corresponding point with the zenith distance Z. During conversion of the linear velocity of the satellite in the photograph to angular velocity in the sphere, one should take into consideration the scale at the given point of the negative, and for cameras with azimuth mounting, the daily rotation of the sky also.

When computing the zenith distance of a satellite, as it was determined above, the equatorial (average) coordinates must be utilized, which have been obtained by conventional methods of photographic astrometry with their conversion from the conventional period of 1950.0 to the period of the satellite's observation with the annual aberration additive and the coordinates of the observation point, whereupon the latitude φ will be converted to the geocentric φ' in accordance to the formula

$$\varphi - \varphi' = 692''62 \sin 2\varphi - 1''11 \sin 4\varphi + \ldots \quad (6)$$

(Strictly speaking, instead of φ' one should use the latitude which has reference to the center of inertia of the absolute terrestrial ellipsoid).

If the altitude H of the observation point is large, then φ' will be converted to this altitude: $\Delta\varphi'$ - is the correction to φ' obtained from:

$$R \sin \Delta\varphi' = H \sin(\varphi - \varphi') \quad (7)$$

$$\Delta\varphi \approx (\varphi - \varphi') \frac{H}{R(\varphi')} \approx (\varphi - \varphi') H \quad (7')$$

If one takes the earth's form to be Krasovskij's ellipsoid and as the unit of distances the equatorial radius of the earth, which is equal to 6378245 m, then the geocentric distance of the $P(\varphi')$ point, which is located on the ellipsoid, is equal to

$$R(\varphi') = \left[1 + 0.0067385 \sin^2\varphi'\right]^{-\frac{1}{2}} \approx 1 - 0.00337 \sin^2\varphi' \quad (8)$$

The geocentric distance R of the observation point and its altitude H above the ellipsoid (accurate up to 200 m coinciding with the altitude above sea level) are associated with the relationships

$$R^2 = R^2(\varphi') + 2R(\varphi') H \cos(\varphi - \varphi') + H^2 \quad (9)$$

or

$$R \approx R(\varphi') + H \cos(\varphi - \varphi') \approx R(\varphi') + H \quad (9')$$

For a satellite, we obtain similar relationships, if in the above presented formulas (6) - (9), φ, φ', $\Delta\varphi'$, R, H are replaced by φ_{cn}, φ'_{cn}, $\Delta\varphi_{cn}$, γ, and H_{cn}.

For ease of computations, we will measure distances in units of the equatorial radius of the earth, the period of rotation in minutes, the mass of the satellites in units of the mass of the earth, and the angular velocity in units of degrees per second. Then for computation with four-five significant digits, that is primarily with that precision which may be obtained during observations using a conventional camera, we obtain (f for the moon):

$$a = 0.0518876\, P^{\frac{2}{3}}$$

$$d = 0.074264\,\mu^{-1} \cos\delta \sqrt{2\gamma^{-1} - a^{-1}} \quad (1')$$

$$= 0.32602\,\mu^{-1} P^{-\frac{1}{3}} \cos\delta \sqrt{2a\gamma^{-1} - 1}$$

$$\tau = R\sqrt{\sin^2 Z + \left[\cos Z + R^{-1} d\right]^2} \qquad (3')$$

If it is required to know the distance to the satellite with an accuracy of two significant digits, then it is convenient to utilize the simplified formulas (2), (1') and (3'), assuming Z to be standard, R = 1, $\tau = 1 + H_{cn}$ and selecting for determination the values $\mu, Z, \delta = 0$ near the culmination. Moreover, if the eccentricity e of the orbit is small, then at the culmination $d = 0.326\mu^{-1} P^{-\frac{1}{3}}$ (1'') with the relative error in $e\%$.

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III

Photographs of the 1958 δ_1 satellite (the rocket-carrier) were obtained in Pulkovo using a conventional camera with a focal distance of 252 mm; the period of rotation of the satellite on November 15, 1958, according to journal information, was P = 93ᵐ.8. The following was obtained in accordance to this data.

Table I

Date	Nov. 13/XI	Nov. 13/XI	Nov. 17/XI	Nov. 17/XI
Point	$12° \pm 2$ before culm.	$Z_{min} \pm 1°.5$	$Z_{min} \pm 1°.5$	10 ± 2 after culm
δ	0°	0°	0°	0°
$\alpha_{1950.0}$	$10^h 05^m 03^s$	$07^h 34^m.8$	$05^h 45^m.8$	$04^h 24^m 08^s$
$\delta_{1950.0}$	$+73° 30'.8$	$+72° 46'$	$+74° 45$	$+67° 24'.3$
UT	$16^h 24^m 45^s.1$	$16^h 25^m 05^s$	$15^h 40^m 04^s$	$15^h 40^m 15^s.4$
Z	$46° 54'.9$	$45° 31'$	$40° 56'$	$41° 38'.9$
μ	0°.5275/sec	0°.5365/sec	0°.5813/sec	0°.5757/sec
τ	1.0929	1.0934	1.0919	1.0919

Thus, in the period November 13-17, 1958, during our observations of the satellite, which was located primarily in the same portion of its orbit, τ was equal to 1.0925 ± 4, and H_{cr} was equal to 606 ± 3 km above the spheroid.

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6. ON THE INFLUENCE OF TIDAL FORCES ON INFLATABLE SATELLITES

The purpose of this paper is to consider whether tidal forces are found to be detrimental for an inflated earth satellite.

Let us evaluate the pressure arising in a spherically inflated earth satellite under the effect of the earth's tidal forces. We will make a coarse excessive estimate. Let us assume that one-half the mass of the satellite's shell is concentrated at a point nearest the earth, and the other one-half at a more remote point. We will compute the difference of the gravitational forces acting upon these masses.

$$d\mathcal{F} = \mathcal{F}' dr = \mathcal{F}' 2\rho$$

where $\mathcal{F}$ - is the force of gravity
r - is the distance from the center of the earth
ρ - is the radius of the spherical satellite

$$\mathcal{F} = -f\frac{Mm}{r^2}$$

$$\mathcal{F}' = \frac{2fMm}{r^3} \qquad |d\mathcal{F}| = \frac{4fMm}{r^3}\rho$$

In the CGS system, the earth's mass is $M = 6.10^{27}$,
$f = 6.7.10^{-8}$,

and let $r = 10^9$, $\rho = 10^3$. The mass of one-half the shell is

$$m = 2\pi\rho^2 td = 6.28.10^3$$

where the thickness of the shell is $t = 10^{-3}$ and the density of the shell substance (the composition material) $d = 1$

Then $|d\mathcal{F}| \approx 10$

Such is the excessive estimate of the internal forces acting on a diametrical section of the shell.

The cross sectional area $S = 2\pi\rho t = 6.28$

The corresponding over-estimated tension arising in the shell is $\delta \approx 1\frac{din}{cm^2} \approx 10^{-3}\frac{g}{cm^2}$

During an increase of the shell's radius, δ increases in proportion to ρ^2 the modulus of rupture of the composition material during static dilation is of the order 100 kg/cm^2 and above. Thus, tidal forces do not represent dangers for the durability of the composition material shell of concrete radius. If one takes the gas pressure P inside the shell to be equal to 10^{-7} gm/cm^2

(the pressure of a high vacum), the tension, arising in the spherical shell as a consequence of the gas pressure will be:

$$\delta = \frac{\rho P}{2t} = 10^{-1}\frac{g}{cm^2}$$

(for a slightly elongated ellipse, the tensions are of the same order). This tension is two orders higher than the tension as a result of tidal forces. Thus, the shell's form will differ little from the spherical one. However, when $P \to 0$, the tidal forces are found to have a substantial effect on the shell's form.

Astronomical Council, Academy of Sciences, USSR

V. A. Tol'skaya

7. RESULTS OF PHOTOGRAPHIC OBSERVATION OF SATELLITES

Photographic observation of the third satellite and its rocket-carrier were carried out using a Maksutov menisceus telescope ($\mathfrak{D}$ = 500mm, $\mathcal{F}$ = 1200mm).

For synchronization of the moments of time with the positions, a parallel plane glass plate [x]. ([x] D. A. Rozhkovskij, V. S. Matyagin, A. V. Kharitonov. " A test of Photographic Observations of Artificial Earth Satellites by means of a Maksutov Meniscius Telescope", /Opyt fotographicheskikh nablyudenij iskusstvennykh sputnikov Zemli s pomoshch'yu meniskovogo teleskopa Maksutova/. Azh (Astronomical Journal), volume XXXV, issue #3, p. 479, 1958.) F 1 1

Time marks, corresponding to definite points of a trace's break, were recorded on the film of a MPO-2 loop oscillograph; within the range of the interpolation interval (3 - 4 seconds), the uniformity of the oscillograph's film movement is sustained strictly with the precision of our computations and measurements. Besides this, on the film of the oscillograph were recorded impulses coming from a printing chronograph; the chronograph, before and after the observation, was checked by six points of the Moscow radio stations. The exception consists of photographs obtained November 24, 1958 and February 26, 1959: for these photographs, time notations, corresponding to portions of the trace's break, were directly recorded by the chronograph. At the above presented moments of time, adjustments were computed for the operation of the relay of the impulse accessory, for the radio wave dispersion and for standard time; the latter was not taken into account only for the instances on December 8, 1958 and February 26, 1959.

Measurement of the rectangular coordinates was accomplished using the UIM-21 universal microscope. The equatorial coordinates of the junction points were determined by Dejch's method using two reference stars. The coordinates presented by us are topocentric.

We assume, on the basis of special computations conducted in our institute, that the error in the determination of the coordinates will not exceed two seconds of an arc.

$\lambda = 5^h 07^m 49^s{,}76 \pm 0^s{,}04 \quad \varphi = 43^\circ 11' 16''{,}9 \pm 0''{,}6$

$h = 1450\,M \pm 50\,M$

1958 δ_1

	Date	UT				$\alpha_{1950.0}$				$\delta_{1950.0}$			
1.	25 July 1958	21^h	30^m	13^s	227	22^h	34^m	52^s	19	$39°$	$09'$	$01''$	5
2.	28 "	19	50	55	652	1	41	42	40	23	37	41	4
3.	29 "	19	51	12	737	0	58	36	42	26	12	05	2
4.	"	21	34	41	733	18	18	13	35	22	02	06	3
5.	30 "	19	50	54	677	23	54	35	824	46	06	14	95
6.	"	21	35	40	911	19	06	57	95	7	42	32	9
7.	31 "	19	49	29	265	22	11	15	62	52	40	15	4
8.	3 August	17	57	05	465	1	47	19	12	43	21	48	8
9.	"	17	42	48	532	18	58	34	073	33	40	15	96
10.	5 "	19	32	17	783	17	10	23	10	30	24	48	7
11.	6 "	19	26	13	845	16	16	19	945	29	47	46	83
12.	7 "	17	36	51	713	23	45	41	713	58	32	10	07
13.	27 October	13	42	26	308	14	10	55	05	45	14	30	4
14.	14 "	23	57	31	304	10	49	55	25	-5	08	12	7
15.	24 November	12	53	56	660	10	17	30	60	73	24	08	2

1958 δ_2

1.	30 July 1958	20	58	24	750	21	16	31	41	22	20	32	8
2.	5 Nov. 1958	13	18	13	905	12	23	02	32	68	58	03	6
3.	8 Dec. 1958	13	50	39	653	21	42	00	94	18	37	27	9
4.	26 Feb. 1959	15	18	51	485	18	41	26	571	73	36	23	99

Observers: Matyagin, Bojko, Rozhkovskij, Kharitonov

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8. LOCATIONS OF THE 1958 δ_1 SATELLITE ACCORDING TO PHOTOGRAPHIC OBSERVATIONS AT PULKOVO

Equipment of Station Number 39. The 1958 δ_1 photographic observations (of the rocket-carrier of the third Soviet artificial earth satellite) were performed using two cameras with a focal length of 253 mm: (A) the standard NAFA-3c/25-C on an azimuth mounting and the (E) modified NAFA-3c/25 at Pulkovo with parallax mounting and with a clock mechanism. The moments of time, corresponding to the opening and shutting of the fast-acting shutters of these cameras, were recorded using chronographs. Conservation of time was achieved in periods of several minutes by printing chronographs with quartz /piezoelectric/ frequency generators and over 24-hour periods by the KL_2 piezoelectric clocks the time service of the VNIIM (Leningrad) (All-Union Scientific Research Institute of Meteorology); the stations performed reception of GBZ-10^h time signals (Criggion)*) by means of the time service radio equipment of the Main Astronomical Observatory (Pulkovo). (*From November 5, 1958, the signals were transmitted by the station GBR-10^h (Rugby).

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Coordinates of the observation points. The geodesic coordinates B, L, astronomical coordinates φ, λ, the absolute altitude H (above sea level) and the excess of the geoid above the ellipsoid h are equal for Camera A:

$$B = +59^\circ 46' 13.''62, \quad L = -30^\circ 19' 42.''07, \quad H = +76.5\,\text{M}, \quad h = 0.0\,\text{M},$$
$$\varphi = +59^\circ 46' 13.''78, \qquad \lambda = -30^\circ 19' 38.''53;$$

for camera E:

$$B = +59^\circ 46' 13.''7, \quad L = -30^\circ 19' 42.''0, \quad H = +76\,\text{M}, \quad h = 0.0\,\text{M},$$
$$\varphi = +59^\circ 46' 13.''9 \qquad \lambda = -30^\circ 19' 38.''5$$

Observations. The film is panchromatic type 10. For improvement of the image qualities, a yellow filter was used. Shutter control was achieved automatically by KL_2 clock, or manually by button. The length of individual exposures of the satellite is 0.08 to $0^s.11$. The stars were exposed two to three times for $3^s \sec \delta$ to $5^s \sec \delta$. From the end of white nights until the rocket's fall to earth, 136 negatives were obtained for 41 transits. After careful selection for accurate measurements, 81 photographs remain for 32 transits. A large portion of the photographs underwent immediate process. The satellite's altitude decreased from 900 to 500 km.

Measurements of the linear coordinates on a photograph were carried out in twos using a UIM-21 instrument with a reversed prism at two of the prism's locations. A single application error is $\pm 3\mu$ (the scale $0^\circ.227$/mm). Clarity of the reference stars is from 5^m to 6^m. The configuration of stars occupied a circle with a diameter not more than 4^o. The distance of the determined point from the optical center, known with an error of $\pm 0\overset{\circ}{.}3$, is not more than 5^o. The number of reference stars on the negative is four. They were measured twice on 52 negatives using three stars each time in which two stars were common.

Computation of the coordinates of the normal point using the trace of the satellite was performed, as a rule, not more than two times, in which in 70% of the instances there were three stars and in 20%, four with "the N-check". The methods of A. N. Dejch were utilized (on 63% of the occasions) and A. A. Kiselev on 35% of the occasions. As was assumed, all necessary corrections were introduced, which amount to 1". In order to exclude errors of the satellite's extreme features, average exposures were utilized. Distortion of the objective ($\leqslant$ 3"), the refracted parallax of the satellite ($\leqslant$ 5"), and the daily rotation of the celestial sphere ($\leqslant 70^s$) were taken into account. As was understood, the annual aberration ($\leqslant 20\overset{"}{.}5$) and the aberrated time ($\leqslant 0\overset{s}{.}008$) were not taken into consideration. For each negative, the astrographic coordinates of the single point were published The Mean Square* error of which has been found according to internal convergence of 190 individual determinations, for α which is $\pm 0\overset{s}{.}15$ sec δ ' and for δ - $\pm$ 2". The problem concerning external accuracy requires additional investigation.

Computation of the moments of time has been performed using the standard time system of the time service, USSR, taking into account all necessary corrections amounting to $0\overset{s}{.}001$. The computations were performed in two ways. As the investigation showed, The Mean Square reading error of the relative moment of time and tying it in to the standard time is $\pm 0\overset{s}{.}002$.* (*In fact, this is the error of moments (without the error of the time scale itself) using the GBZ system, to which if necessary it is not difficult to convert, having used the bulletin "Standard Time...".) The Mean Square error of the published moment $U.T._E$ is $\pm$ $0\overset{s}{.}005$.

It is necessary to keep in mind the computation of the time for the normal point was carried out using several chronograph readings, and checking of the chronograph's movement was achieved,

*Tr. Note: In Russian CP.KB., I believe it expands to СРЕДНИЙ КВАДРАТ but I cannot find proof of this.

immediately before and after the individual photograph, by tens of clock signals, which for a period of several minutes were of good quality. Thus, for an aggregate of observations of the same transit using the same camera, the internal Mean Square error obtained is equal to $\pm 0^s.001$.

Determination of the visual angular velocity $\mu > 0$ and of the positional angle $0^\circ \leqslant \theta < 360^\circ$, counted from the declination circle prior to the satellite's movement toward the increase of right ascensions, was performed with an approximate accuracy of ± 0.01 degrees per second and $\pm 1^\circ$ respectively. Angle θ was determined by means of an astral chart.The values /of/ μ and θ are strictly given at the point (α, δ, UT_E). They are presented for an accurate comparison of the reading of the position coordinates and the time coordinate (according to the trace, $\Delta\rho'' = 3.6\mu\ \Delta UT_E^{ms}$), and also for the selection of points (α, δ, UT_E) in general, in accordance to the accuracy criterion of their reading; within known limits, conversion of a point (α, δ, UT_E) to another close point; and, moreover, knowledge of supplementary data of μ and θ is useful in certain other questions.

Operational accomplishments.

Observations: B. A. Firago (F), G. V. Panov (P), D. E. Shchegolev (Shch).

Measurements and computations: T. E. Syshchenko, G. V. Panov, Shch. E. Shchegolev and B. A. Firago.

Processing results are set forth below. In the columns are presented:

1. Numerical order

2. Camera A or Ē

3. Family name of the observer and number of the negative.

4. Date in 1958

5. Moment of world time in the standard time system UT_E.

6. Correction of $TU_2 - UT_E$ is in units of $0^s.001$ for conversion from standard time to the approximately uniform international time TU_2.

7 and 8. Astrographic coordinates of the satellite, -- right ascension and declination for the period 1950.0, -- α 1950.0 and δ 1950.0

9. The angular velocity μ is in units of degrees per second and

10. the positional angle θ of the direction of the satellite's movement at the point (α , δ , UT_E).

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No.	Camera	No. of photograph	Date in 1958	μ in degrees per second
1	A	*111	29-7	0.59
2	A	*112	29-7	0.56
3	A	*113	29-7	0.36
4	A	*116	29-7	0.22
5	A	*120	01-8	0.25
6	A	*121	01-8	0.47
7	A	*122	01-8	0.56
8	A	*123	01-8	0.42
9	A	*124	01-8	0.23
10	A	*125	01-8	0.25
11	A	*127	03-8	0.41
12	A	*128	03-8	0.50
13	A	*129	03-8	0.34
14	A	*131	03-8	0.22
15	A	*132	03-8	0.20
16	A	*133	04-8	0.23
17	A	*134	04-8	0.45
18	A	*135	04-8	0.32
19	A	*139	12-8	0.25
20	A	*140	12-8	0.32
21	A	*143	13-8	0.25
22	A	*144	13-8	0.17
23	A	*145	25-9	0.62
24	A	*146	25-9	0.90
25	A	*149	28-9	0.23
26	A	*151	28-9	0.50
27	A	*152	28-9	0.59
28	A	*154	29-9	0.69
29	A	*156	29-9	0.36
30	A	*157	03-10	0.59
31	A	*158	03-10	0.36
32	A	*159	03-10	0.29
33	A	*161	03-10	0.48
34	A	*163	04-10	0.17
35	A	*169	10-10	0.50
36	A	*171	11-10	0.46
37	A	*177	14-10	0.46
38	A	*178	14-10	0.42
39	A	*179	14-10	0.25
40	A	*180	14-10	0.15
41	Φ	** 33	28-10	0.26
42	A	*181	28-10	0.29
43	A	*182	28-10	0.55
44	Φ	** 35	06-11	0.61
45	A	*184	13-11	0.18
46	A	*185	13-11	0.37

No.	Camera	No. of photo-graph	Date in 1958	μ in degrees per second
47	A	*186	13-11	0.53
48	A	*188	17-11	0.31
49	A	*189	17-11	0.57
50	A	*190	17-11	0.64
51	⊕	** 42	17-11	0.45
52	A	*191	17-11	0.39
53	A	*193	17-11	0.13
54	A	*194	17-11	0.24
55	A	*195	18-11	0.26
56	A	*196	18-11	0.48
57	A	*196	18-11	0.51
58	⊕	** 44	18-11	0.51
59	A	*197	18-11	0.51
60	⊕	** 45	18-11	0.52
61	A	*198	18-11	0.42
62	A	*199	18-11	0.27
63	A	*201	19-11	0.47
64	⊕	+ 45	19-11	0.59
65	A	*205	19-11	0.79
66	A	*206	19-11	0.74
67	A	*207	19-11	0.45
68	⊕	** 48	22-11	0.52
69	⊕	** 49	22-11	0.65
70	⊕	** 50	22-11	0.64
71	⊕	** 51	22-11	0.39
72	A	*212	23-11	0.23
73	A	*213	23-11	0.41
74	A	*214	23-11	0.63
75	A	*215	23-11	0.79
75	A	*216	23-11	0.63
77	A	*217	23-11	0.29
78	A	*220	26-11	0.61
79	A	*221	26-11	0.43
80	A	*222	26-11	0.23
81	A	*224	27-11	0.36
82	A	*225	27-11	0.25

* = F   + = Shch

** + P   ⊕ = Ē

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$\lambda = 03^h53^m23^s$ $\varphi = 37^0 57' 19''$ H=234M

NAFA /Night Aerial Camera/ Camera 3c/25

1957 β

	Date	U. T.	α 1950.0	δ 1950.0
1	March 18	$15^h17^m24^s.706$	$07^h16^m17^s$	$-38^o17,4$
2	"	15 17 27,609	07 20 12	-37 42,0
3	"	15 17 29,692	07 23 19	-37 14,7
4	"	15 17 32,664	07 27 29	-36 35,9
5	"	15 17 34,648	07 30 24	-36 08.6
6	"	15 17 36,632	07 33 20	-35 40,0
7	"	15 17 38,995	07 37 09	-35 04,7
8	"	15 17 52,227	07 59 03	-31 14,2
9	"	15 17 53,577	08 01 27	-30 47,6
10	March 20	00 48 56,792	13 16 26	+34 24,2
11	"	00 49 00,251	13 22 22	+33 25,7
12	"	00 49 02,127	13 25 31	+32 53,3
13	"	00 49 03,822	13 28 21	+32 23,6
14	"	00 49 14,481	14 01 38	+25 46,5
15	"	00 49 28,306	14 06 51	+24 35,0
16	"	00 49 32,788	14 13 21	+22 39,7
17	"	00 52 14,350	16 46 09	-23 05,5
18	"	00 52 15,341	16 46 41	-23 15,2
19	"	00 52 18,176	16 48 15	-23 42,4
20	"	00 52 19,438	16 48 55	-23 54,4
21	"	00 52 20,347	16 49 20	-24 01,8
22	"	00 52 44,845	17 01 40	-27 35,6
23	"	00 52 46,598	17 02 30	-27 49,5
24	"	00 52 47,044	17 02 45	-27 53,0
25	"	00 52 49,249	17 03 09	-28 17,5

A. P. Savrukhin, R. L. Khotinok and B. E. Bereda participated in the photographic observations. Kiselev's method /was used/ for processing. Measurements were accomplished using a UIM-21 microscope. A. P. Savrukhin, and A. F. Chervyakova took part in the processing. Accuracy in determining the time moments is $\pm 0^s.005$. Accuracy of positions /locations/ is $\pm 0''.2$.

Chief of AES Observation Stations A. P. Savrukhin

Tartu State University

$\varphi = 58^{\circ}22'47''$ $\lambda = 1^h46^m53^s.2$ h = 68M

Camera NAFA 3c/25 Film Panchromatic, type 10

1958 δ_1

	Date	U. T.	α 1950.0	δ 1950.0
1.	28 October	$2^h45^m38^s.83$*	$18^h58^m15^s$	$+72^{\circ}08'.7$
2.	3 November	16 29 13,12*	15 37 22	+55 31,8
3.	3 "	16 29 49,49*	13 24 40	+78 21,9
4.	3 "	16 30 45,94*	5 46 32	+64 13,0
5.	17 "	15 38 22,96*	11 39 42	+56 25,2
6.	17 "	15 40 26,04*	4 36 08	+51 37,0
7.	19 "	15 45 27,34*	13 10 56	+41 00,2
8.	19 "	15 48 07,82*	3 48 27	+64 36,8
9.	19 "	15 48 35,95*	3 05 30	+50 23,7

1958 δ_2

1.	23 Feb.1959	$16^h36^m14^s.762$	$14^h23^m56^s$	$+82^{\circ}46'.9$
2.	23 " "	16 37 19,803	11 44 30	+69 33,3
3.	2 March "	16 42 38,848	7 01 55	+80 33,0

$\varphi = 58^{\circ}22'47$ $\lambda = 1^h45^m53^s.3$ h=68M

1958 δ_1

1.	16 Oct.1958	1 48 18,48*	22 31 53	+72 33,8
2.	28 " "	16 58 01,63*	20 31 05	+ 9 58,3

1958 δ_2

1.	14 April 1959	1 27 20,074	16 25 22	+58 01,9

Observers: T. Kipper, Ya. Ejnasto, L. Luud, L. Utter and E. Kreem

Processing: M. Lijgant, S. Lepoik, L. Utter

Measurements were performed using a UIM-21; Kiselev's method /for/ processing.

Chief of the Tartu State University (TGU) M. Lijgant

*) Time is determined by the "six-points" radio signals. Only the average signal delay is taken into account.

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Results of Precise AES Photographic Observations

Satellite 1957 β - No. 1, 2, 3, 6, 7, 8, 10.

Rocket-Carrier 1958 δ_1 - No. No. 2, 3, 4, 6, 7, 8, 9, 10.

Satellite 1958 δ_2 - No. No. 2, 4, 7, 9, 10.

Bibliography - No. No. 1, 3, 1958.

APPENDIX I

Table I

Observations of AES 1958 δ_2 (Soviet)

(Information secured from Russian observation station telegrams)

Station No.	Name of Station	November: No. of Observation	November: No. of Transits	December: No. of Observations	December: No. of Transits
1	Abakan	5	3	3	2
2	Alma-Ata	2	2	-	-
3	Abastuman	0	0	-	-
4	Arkhangel'lsk	64	11	62	11
5	Astrakhan'	4	2	4	1
6	Ashkhabad	15	4	1	1
7	Baku	-	-	-	-
8	Baranaul	12	2	-	-
9	Batumi	2	1	1	1
10	Blagoveshchensk	63	14	49	14
11	Bukhara	7	4	-	-
12	Vil'nyus	17	4	10	3
13	Vladivostok	19	7	10	4
14	Vologda	35	8	26	5
15	Voronezh	16	7	7	2
16	Gor'kij	14	7	5	2
17	Dnepropetrovsk	-	-	1	1
18	Yerevan	29	7	2	1
19	Irkutsk	2	2	4	4
20	Kazan'	20	9	11	5
21	Karaganda	21	6	7	4
22	Kzyl-Orda	6	4	-	-
23	Kiev	16	3	4	1
24	Kishinev	0	0	-	-
25	Komsomol'sk on the Amur	21	10	14	8
26	Krasnoyarsk	10	3	5	2
27	Krasnodar	1	1	24	6
28	Crimea Observatory	6	3	5	2
29	Kurgan	27	6	20	8
30	Leningrad	30	9	-	-
31	L'vov	8	3	4	1
32	Perm	9	4	-	-
33	Minsk	6	2	4	2
34	Moskow	11	4	3	2
35	Novosibirsk	1	1	6	2
36	Odessa	1	1	-	-
37	Imsk	34	5	13	4

38	Petrozavodsk	15	5	23	13
39	Pulkovo	24	11	15	4
40	Riga	5	2	30	9
41	Rostov-Don	1	1	7	2
42	Ryazan'	57	12	30	6
43	Samarkand	2	1	1	1
44	Saratov	84	14	6	2
45	Sverdlovsk	26	10	6	4
46	Smolensk	17	8	6	5
47	Stalinabad	0	0	-	-
48	Stalingrad	61	7	11	3
49	Syktyvkar	16	9	12	4
50	Gorkij	11	8	4	3
51	Tartu	2	1	21	8
52	Tashkent	12	2	-	-
53	Tbilisi	0	0	2	1
54	Tomsk	12	6	6	4
55	Uzhgorod	-	-	-	-
56	Ulan-Ude	3	3	7	7
57	Ufa	33	13	10	5
58	Frunze	33	5	-	-
59	Khabarovsk	85	10	7	4
60	Khar'kov	16	6	5	2
61	Chardzhou	20	7	-	-
62	Chernovtsy	4	2	2	1
63	Orenburg	30	11	25	8
64	Chita	19	9	12	8
65	Yuzhno-Sakhalinsk	5	4	7	2
66	Yakutsk	5	2	6	3
67	Alma-Ata	1	1	-	-
68	Stalinabad	-	-	-	-
69	Kungur	2	2	-	-
70	Kiev GAO	-	-	-	-
71	Ul'yanovsk	19	7	12	8
72	Astrosoviet Moscow	3	2	3	2
73	Odessa	-	-	-	-
74	Ashkabad	-	-	-	-
75	Tashkent i/m Engel'gardt	7	2	-	-
76	Observatory i/m Engel'gardt	53	12	19	6
77	Nikolaev	0	0	1	1
79	Yaroslavl'	23	6	24	5
80	Nal'chik	-	-	-	-
81	Gomel'	29	4	9	3
82	Byurakan	-	-	-	-
83	Tartu	-	-	-	-
84	Riga	-	-	3	3

153		Cracow	-	-	-	-
154		Poznan	-	-	-	-
155		Warsaw	-	-	-	-
156		Glinya	-	-	-	-
157		Zegzhe	-	-	-	-
158		Elenya Gura	-	-	-	-
159		Torun II	-	-	-	-
160		Yuzefoslavyu	-	-	-	-
	Japan		23	37	-	-
271	China	Peking	7	17	4	10
272		Nanking	2	5	4	6
273		Lanchzhou	2	5	-	-
274		Kunmin	7	24	-	-
275		Lkhasa	-	-	-	-
276		Canton	8	20	-	-
277		Sian'	5	14	1	4
278		Zi-Ka-Vej	1	3	1	1
279		Ukhan'	2	11	-	-
280		Chan'chun	13	43	12	47
281		Urumchi	4	12	-	-
282		Tientsin I	8	24	7	21
283		Zo-Ze	-	-	-	-
284		Harbin	10	16	9	41
285		Khukhekhaote	8	17	6	10
286		Chzhenchzhou	6	14	4	6
287		Sinin	3	18	3	17
288		Chendu	-	-	-	-
289		Tsindao	1	4	4	7
290		Fuchow	2	3	-	-
291		Nanin	6	22	-	-
292		Shan'tou	4	20	1	6
293		Tientsin II	-	-	-	-
301	Argentina	Tukuman	-	-	-	-
302		Buenos Aires	-	-	-	-
303		Pergamino	-	-	-	-
304		Merlo	-	-	-	-
305		Cordova	-	-	-	-
306	Chile	Santiago	-	-	2	2
307	Uruguay	Montevideo	-	-	-	-
308	Ecuador	Quito	-	-	-	-
309		Guangiltagua	-	-	-	-
321	Peru	Arequipa	-	-	-	-
322		Uankajo	-	-	-	-
332		Ankon	-	-	-	-
351	Brazil	Sao Paulo	-	-	-	-
352		Bauru	-	-	-	-
401	Great Britain	Jodrel Bank	-	-	-	-
402		Cambridge	-	-	-	-
403		Greenwich	-	-	-	-

404		Edinburg	-	-	-	-
405		Herford	-	-	-	-
406		Slough	-	-	-	-
410		Farnborough	4	4	-	-
		Other Stations	-	-	-	-
407	Ireland	Dublin	-	-	-	-
450	France	Medon	-	-	2	27
451		Pic-du-Midi	2	17	-	-
471	Austria	Vienna	-	-	-	-
472		Kantsel'khoe	-	-	-	-
501	Yugoslavia	Belgrad	2	6	1	4
502		Zagreb	-	-	-	-
503	Greece	Athens	-	-	-	-
504		Pentele	2	3	-	-
505		Spetsai	-	-	-	-
506		Thessalonika	-	-	-	-
507		Ikariya	-	-	-	-
520	Italy	Merate	-	-	-	-
551	Pakistan	Dakka	-	-	-	-
552		Kvetta	-	-	-	-
571	Indonesia	Djakarta	-	-	-	-
572		Lembang	-	-	-	-
581	Viet Nam	Hanoi	-	-	-	-
582		Sha-pa	-	-	-	-
601	Australia	Canberra	-	-	-	-
602		Sidney	-	-	-	-
603		Perth	-	-	2	4
604		Adelaide	1	1	-	-
605		Melbourne	-	-	1	1
606		Voomera	-	-	-	-
660	Mongolia	Ulan-Bator	6	11	4	4
771	Canada	Ottawa	-	-	-	-
772		Richmond Hill	-	-	-	-
773		Atabaska	-	-	-	-
774		Newbrook	-	-	-	-
775		Royal Oak	-	-	-	-
776		Saskatun	-	-	-	-
777		Volkarter	-	-	-	-
801	Holland	Station No. 1	-	-	-	-
802		" 2	-	-	-	-
803		" 3	-	-	-	-
804		" 4	-	-	-	-
805		" 5	-	-	-	-
806		" 6	-	-	-	-
807		" 7	-	-	1	1
808		" 8	-	-	-	-
809		" 9	-	-	-	-
810		" 10	-	-	6	16
811		" 11	-	-	-	-

812		Station No. 12	-	-	-	-
813		" 13	-	-	-	-
814		" 14	-	-	-	-
815		" 15	-	-	-	-
816		" 16	-	-	1	1
817		" 17	-	-	-	-
818		" 18	-	-	-	-
901	UAR	Cairo	-	-	-	-
930	So. Africa	Johannesburg	-	-	-	-
931		Blomfontain	-	-	-	-
932		Capetown	-	-	-	-
9002		Olifantsfon-tain	-	-	-	-
942	Finland	Niinisalo	-	-	-	-
963		Jokiojneh	-	-	14	209
	American Stations for photographic observations of the AES		14	15	9	10
		TOTAL	166	424	106	472

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